A Study on Road Control Radar System in Smart Highway

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ABSTRACT

A Smart Highway is a next generation highway that significantly improves a traffic safety, reduces incidence of traffic accidents, and supports intelligent and convenient environment so that drivers can drive at high speeds over 160 km/h. In order to achieve the goal, it is required to gather a large amount of information including conditions of a road and drivers, the status of vehicles, and other useful data. The road condition in particularly is an extremely important factor among them.

In this paper, we suggests a Road Control Radar System, RCRS, as a solution to detect road conditions using a radar system independent of weather conditions or the time of the day. RCRS is a real-time system that delivers considerably large amount of data including road conditions such as dry, wet, water-film, snow or ice road surface and dangerous obstacles on the road to drivers and central servers using a radar system for detecting them. As a result, it is expected to prevent traffic accidents in advance by offering rapid and accurate information to drivers.

1. INTRODUCTION

1.1 Motivations

Smart highway[1] is a next generation highway that supports fast and safe driving environment. To support the environments, it is essential that analyzing road status precisely and offering the information to drivers in any-time and any-weather. Although current highway offers useful information, such as realtime traffic status, using CCTV or various sensor devices[7] to drivers, it has limitations; it is hard to gather accurate information in whole road and to maintain the system[6]. Especially, current system cannot gather needed status data accurately during night time or in bad weather.

Using radar, the road conditions, such as dried, waterfilmed, iced, snowed status or dangerous obstacles, can be quickly detected. Data gathered by radar should be processed to be delivered to the central server or vehicles. Constructing a fast local network infrastructure is required to deliver critical information, such as car accidents or dangerous obstacles. Developing a vehicle embedded terminal receiver which takes and displays standardized information is also required.

1.2 Remarkable Features

Existing methods, using IR (Infrared Rays) camera, have been proposed to gather and detect the status of road surface. Although IR camera provides accurate information in good weather, it has a limitation that it cannot capture accurate images in bad weather[2]. Table 1 shows the attenuation rates of various image detecting devices.

Table 1. The attenuation rates of various image detecting devices

Detecting Devices	Attenuatioin Rates	Features	Applications
Centimeter-wave Radar (34G, Active)	0.05/1 (10G case)	all-weather, all-time, wide angle	Target/velocity/movement detection

Millimeter-wave Radar (47G, Active)	0.2/4.7	all-weather, all-time, wide angle	Target/velocity/movement detection
Radiometer (94G, Passive)	0.5/9.4	all-weather, all-time, wide angle, no exposure	Target detection only
IR Camera	0.04/7000	all-time, narrow angle, no exposure	Target detection only (Huge data size)
Visible Ray (VLCamera)	0.5/50,000	narrow angle, no exposure	Target detection only (Huge data size)
Laser Radar (Active Radar)	0.5/100.000	Exposure	Target/velocity/movement detection (Huge data size)

As shown in the Table 1, light attenuation is low in radar while it is high in visible ray. Using radar, it is possible to overcome the limitation of current detecting systems and construct road control system which detects all events in all time.

2. RELATED WORKS

2.1 Radar

Radar, which is an abbreviation of Radio Detecting and Ranging, is an object detection system that uses electromagnetic waves to identify the range, altitude, direction or speed of both moving and fixed objects such as aircraft, ships, motor vehicles, weather formations, and terrain. Although many types of radar exist, we researched three of them from the perspective of road control system.

Active radar:

Radar system contains both transmitter and receiver.

- Tracking radar: Two types of chase radar exist; one is a skin tracking radar that uses signals reflected by the target's skin, and the other is a beacon tracking radar that tracks response signals by the target.
- Detection radar: Various classifications exists based on a location of a target or a observable range of the radar. Mainly used for military purposes.
- Main usages: Estimation of distance to a target, relative to the velocity of a target, and number of target objects (e.g. traffic density)

Active image radar:

Image radar contains both transmitter and receiver.

- RAR (Real Aperture Radar): RAR synthesizes images without considering phase contrast. The horizontal distance resolution, therefore, varies as a distance to target changes. Most of SLARs are of this type.
- SAR (Synthetic Aperture Radar): Most of modern image radars are of this type. SAR has a fixed horizontal distance resolution since it uses the focal point considering the phase contrast.
- Applications: Ground observations and chasing moving objects through images obtained

Passive image radar:

Image radar consists of only receiver. It detects objects by sensing energies of them.

- Imaging radiometer (Radio wave camera): Use radiant heat made by millimeter-waves. Visualization is usually done using the photoelectric effects.

2.2 Structure of a radar system

Figure 1 shows a typical radar system which consists of a transmitter, a receiver, an antenna, a signal processor, and a management console.

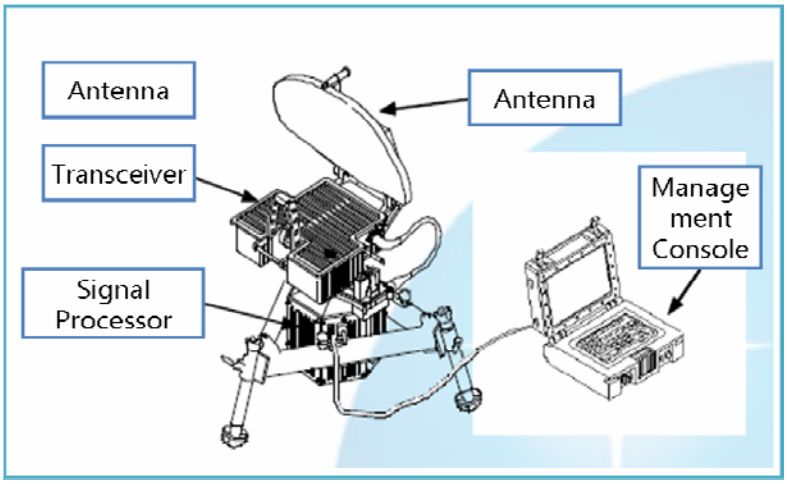

Figure 1. The typical structure of radar systems

Pulses of radio waves or microwaves, transmitted by the antenna, bounce off any object in their path. The object returns a part of wave's energy to the antenna, which is usually located at the same site as the transmitter. The object alters the original waves by causing several effects, such as Doppler effects, and the change is reflected on the returned waves. The signal processor inspects the returned signal and the system can estimate the size, the distance, and the speed of the object. Management console displays the signal of the object in a screen and also controls other parts of the system. Figure 2 shows the flows of signals in a typical radar system.

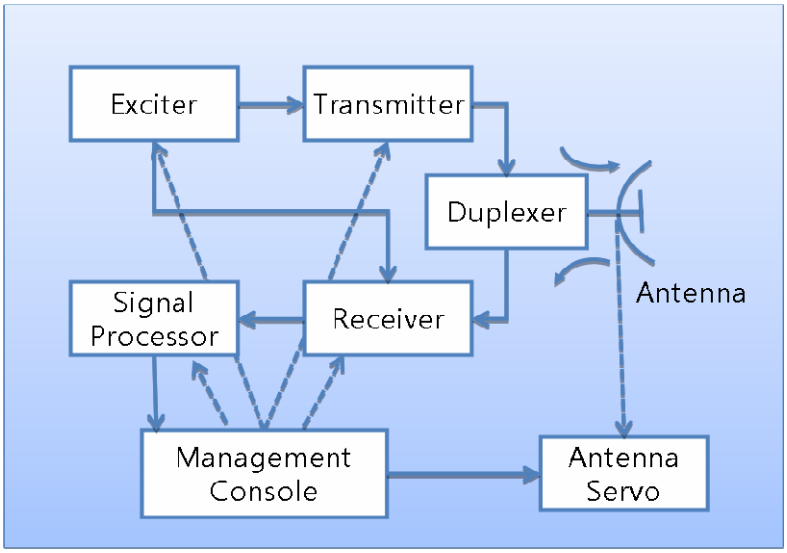

Figure 2. The flows of signals in radar systems

2.3 Related Works

So far, there have been number of attempts to collect road status data.

Road condition detecting system using CCTV:
The system estimates the condition of the road surface using images taken by CCTV. The proposed algorithm analyzes the images and determines the various road conditions, such as dry, wet, icy, or snowed. The system does not require building additional equipments, like extra sensor devices since it uses existing CCTV. The system also has a benefit that wide range of roads can be examined. But the system is not quite useful in real situations since it cannot detect accurate conditions in unfavorable weather which is a situation that the accuracy really matters. Figure 3 shows road surface images taken by CCTV and its analysis results.

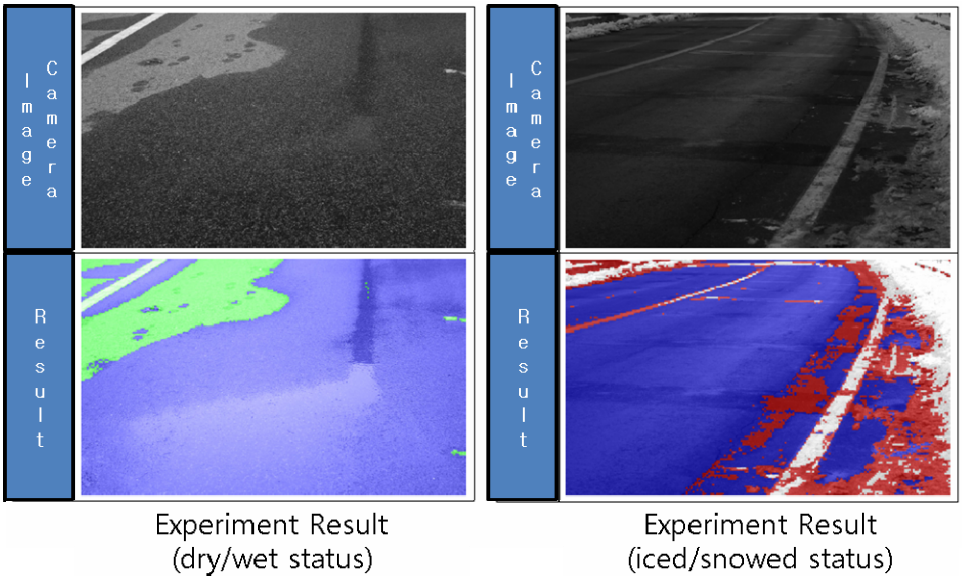

Figure 3. Images taken by CCTV and analysis results

Realtime traffic analyzing system using radar:

The system exploits radars installed at 5 meters high. The radar can observe 4 lanes in each way. The main purpose of the system is not to detect road conditions but it usually estimates a traffic density of the road. Figure 4 shows a radar system that estimates the traffic density.

Figure 4. A radar system that estimates the traffic density

Road condition detecting system using radiometer:

AHSRA (Advanced Cruise-Assist Highway System Research Association)[3] project in Japan which aims for building vehicle-highway cooperation, implemented a road condition detection system using radiometer. The detecting sensors, based on 95GHz radiometer, can observe three lanes in each way by 40 meters ahead in all-time and in all-weather. And the system delivers the road condition, such as dry, wet, water-filmed, iced, or snowed, to vehicles in real time. Figure 5 shows the principle of radiometer and photograph of radiometer.

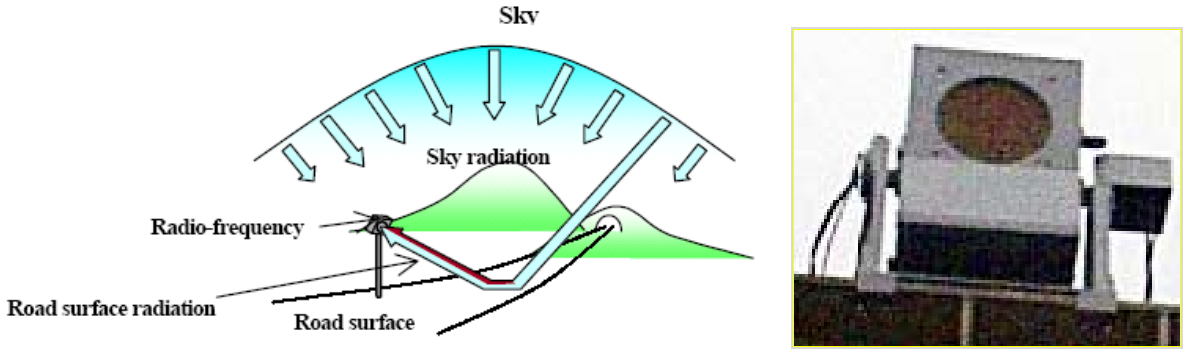

Figure 5. Principle of Radiometer and Photograph of Radiometer

Obstacle detecting system using radar:

Obstacle detecting system using 60 GHz millimeter-waves was developed in Japan[4]. The system can detect various obstacles on the road. And if dangerous situation occurs, it delivers easy-to-understand information to vehicles so that they can avoid accidents. The radars are installed at 10 meters high or less and their observable range is from 25 to 100 meters wide. Figure 6 shows the effectiveness of radar sensors by informing vehicles who cannot detect danger situations due to their visible ranges[9].

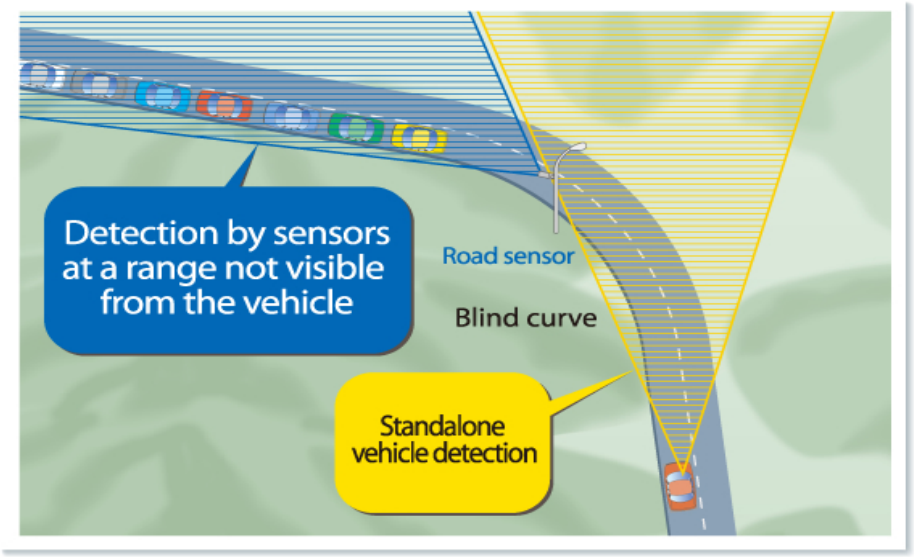

Figure 6. Effective usage of radar sensors

3. BUILDING THE ROAD CONTROL RADAR SYSTEM

3.1 Road Control Radar System(RCRS)

Road Control Radar System is a system that detects various conditions of a road surface using radar in all-time and all-weather. The system delivers the information to the vehicles in realtime so that drivers can prepare for unprepared situations and avoid accidents. All information gathered by local radar is sent to central server which manages overall situations by collecting local information.

3.2 The goal

The Road Control Radar System is an essential part of Smart Highway. The target situations of the system are following.

- Obstacles to stop: icy road, water-filmed road
- Obstacles to see: fog

- Obstacles to move: fallen objects

Those obstacles should be detected and informed to drivers in realtime so that Smart Highway can support safety, speed and regularity.

3.3 Technical Details

3.3.1 Technology to detect conditions of road surface using radar

The radar should satisfy following requirements for easy installing and accurate operations.

Antenna

The size of antenna should be less than 50 centimeters for easy installing. The azimuth resolution should be maximized by using Phased Array Antenna and making its beam range less than 1 degree.

Frequency

The appropriate frequencies are bandwidth of centimeter waves or millimeter waves. The bandwidth from X band to W band (about 9 GHz ~ 100 GHz) is under consideration.

Amplifier

An amplifier which influences a size and an output of the radar is about to be made of a solid-state semiconductor.

Output

The output of the radar should be carefully chosen considering observation range and clutter.

3.3.2 Immobile state recognition radar system

Immobile radar system should collect various data and be able to process them. It should also store and manage collected and analyzed data by itself. The system should be controlled remotely. The requirements of the radar, such as observable range and resolution and the positions where the radar would be installed, should be established. Figure 7 shows how immobile state recognition radar systems work.

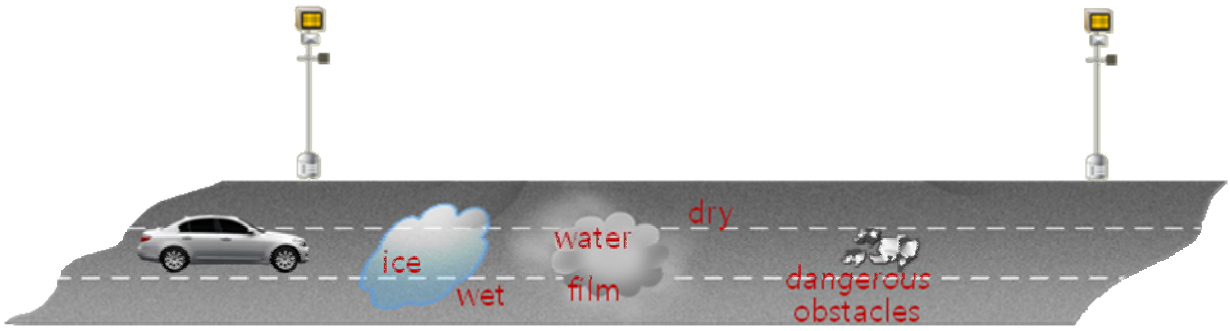

Figure 7. Immobile state recognition radar systems

3.3.3 Technologies to convert and analyze collected data

A high-level signal processing technology that enables the system to acquire accurate conditions of road surface by eliminating ground clutters is a key to analyze the data gathered by the radar. Adaptive beamforming technique is also required to minimize the multiple reflecting signals and to eliminate interference signals[8]. The conditions of the road surface can be obtained by analyzing parameters of the signals, such as height, distance, and weather conditions the radar gathered.

3.3.4 Technology to deliver analyzed data to system administrators

There should be an effective mechanism to deliver administrators data collected and analyzed by the radar system. The mechanism is based on technologies such as data transmission between local radar system and central server[5], data communication among neighboring systems and monitoring distributed systems by central server. Figure 8 shows the communication among each system component.

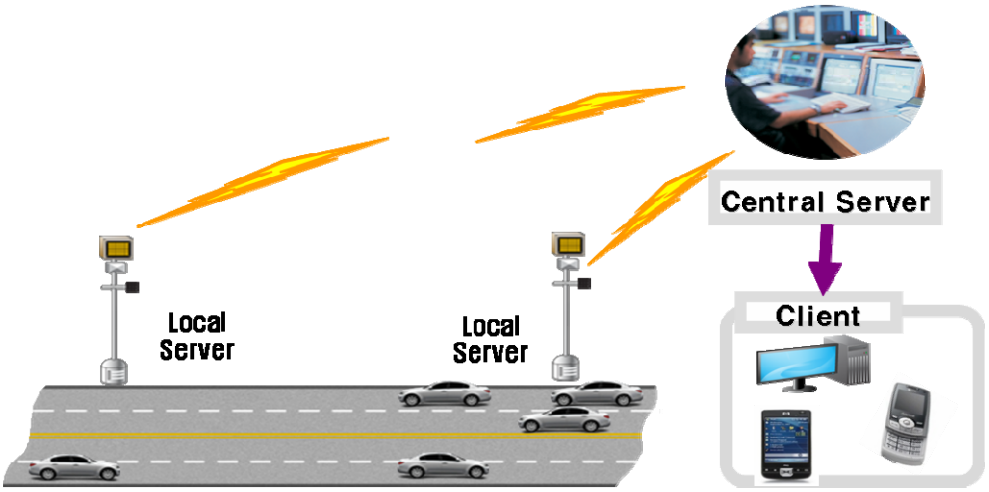

Figure 8. Data communication among various statioins

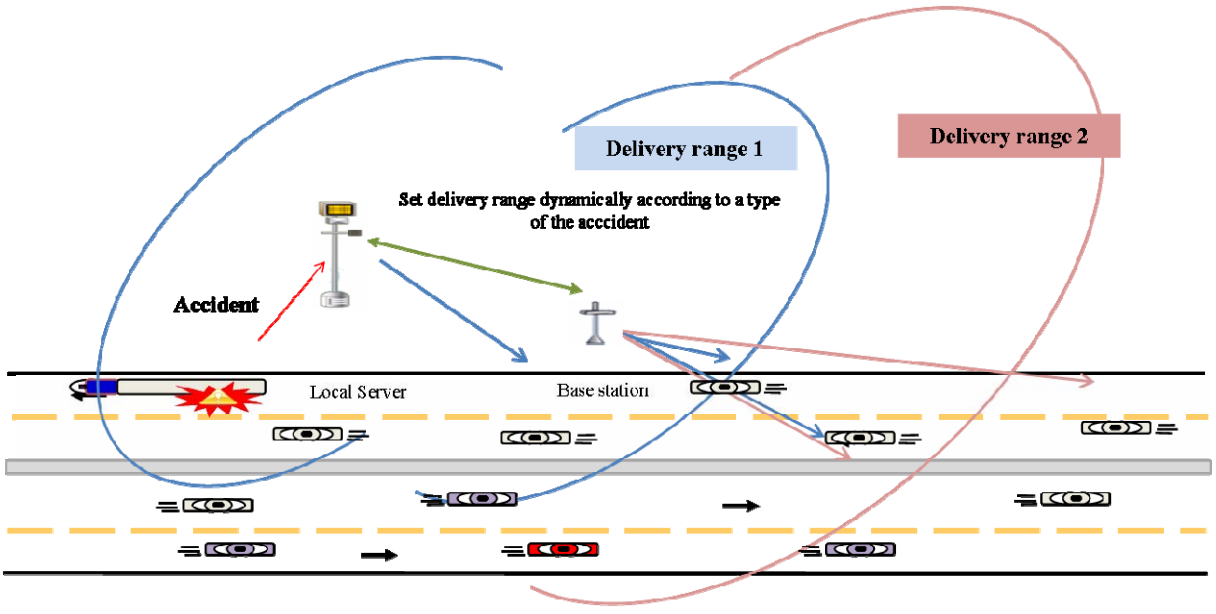

Figure 9. Dynamic set of delivery ranges according to types of accidents

3.3.5 Technology to deliver information to vehicles

The data collected by the radar system is only meaningful when it is delivered to drivers so that they can be prepared for situations safely. Hence, there should be an algorithm that estimates the transmission scope according to not only a type of the danger situation but also traveling velocity of the vehicles. Figure 9 shows setting different delivery ranges according to the type of the accident.

3.4 Strategy to promote

We have the following strategies to build the Road Control Radar System.

- Examination of current radar technologies if they are applicable to the system
- Quantification of information that is collected by radar through in and out door electric wave experiments
- Confirmation of the radar specifications and building the system after on the spot tests of applicable radars
- Verification of availability and performance improvements through thorough on the spot tests
- Setting up the radar system and development of the management policy of the system based on performance and economical efficiency
- Putting the system to practical use

3.5 Expected effects

The Road Control Radar System is expected to play an essential role in successful constructing of Smart Highway. At the present, the fields practically using radar are limited to military, weather observation and aerospace engineering. By exploiting the radar system in road traffic engineering, the market of radar will grow.

4. CONCLUSIONS AND FUTURE WORKS

4.1 Conclusions

In this paper, we investigate Road Control Radar System that detects road status using radar technology and delivers the information to drivers in real time. Applying radar technology to road control system can overcome the limitations of current system, since precise road status can be detected even in all-time and in all-weather. Road Control Radar System will be essential in building Smart Highway.

4.2 Future Works

Our future works include the development, the construction, and the benchmarking of Road Control Radar System in a real world. Our future works also include intensive test of the radar system because it is hard to predict and apply the system in real situations without being ensured by going through proper and complete tests.

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